CRD-C 654-95

Standard Test Method for Determining the California Bearing Ratio of Soils*

1. Scope.

1.1 This test method is used for determining the California Bearing Ratio (CBR) of soils either in the field or in the laboratory.

2. Apparatus.

2.1 *Cylinder mold.* Cylinder mold assembly meeting the requirements indicated in Figure 1. For any group of molds, one extra baseplate is desirable because two plates are required when a mold is inverted during the preparation of the specimen.

2.2 *Disk.* Disk as shown in Figure 1.

2.3 Tamper. Compaction tamper as shown in ASTM D 1557.

2.4 *Measuring apparatus.* Apparatus for measuring expansion of soil, consisting of adjustable stem and perforated plate, tripod, and dial micrometer (reading to 0.001 in.), as shown in Figure 1.

2.5 *Masses.* Masses, including one annular surcharge mass and several slotted or split surcharge masses as shown in Figure 1.

2.6 *Soaking tank.* Soaking tank of sufficient size to accommodate several test molds and of sufficient depth to ensure submergence of the sample.

2.7 *Penetration piston.* Penetration piston as shown in Figure 1.

2.8 *Loading device.* Loading device, either a laboratory testing machine or screwjack and frame arrange

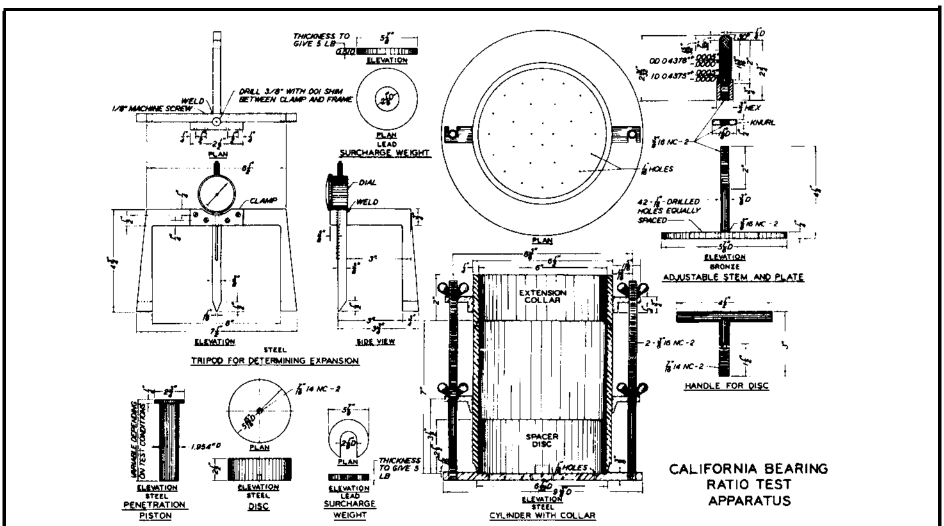


Figure 1. California bearing ratio test apparatus

* Formerly MIL-STD-621A. Method 101, 22 December 1964

ment (as illustrated in Figure 2). which can be used to force the penetration piston into the specimen at a uniform rate of 0.05 in. per minute.

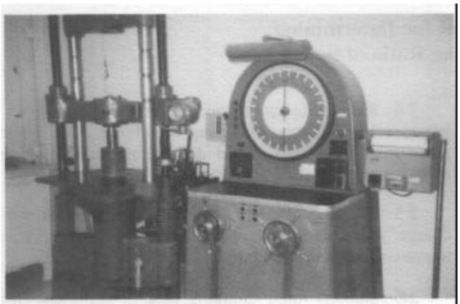


Figure 2. Laboratory CBR Test equipment

2.9 *General laboratory equipment. General* laboratory equipment specified in CRD-C 653.

2.10 *Loading device.* Loading device consisting of a mechanical screwjack to apply the load and a loaded truck to provide the resistance for the screwjack (see Figure 3).

2.1.1 *Proving rings.* Calibrated proving rings.

2.12 *Penetration piston.* Penetration piston, 1.95 in. in diameter, with internally threaded pipe extensions and connectors.

2.13 *Micrometers.* Dial micrometers and support.

2.14 Steel plate. Steel plate, 10 in. in diameter, having a 2.03-in.-diameter hole in the center and weighing 10 lb.

3. Procedure.

3.1 *Penetration test procedure.* The following penetration test procedure applies to laboratory and field in-place CBR tests. Satisfactory forms for recording penetration data for laboratory tests and field tests are shown in Figure 4 and Figures 5 and 6, respectively.

3.1.1 *Applying surcharge.* Apply sufficient penetration surcharge on the soil being tested to produce an intensity of loading equal to the weight (within ±5 lb) of the base material and pavement that overlie the soil being tested, but the surcharge weight shall be not less than 10 lb. If the sample has been soaked previously, the penetration surcharge must be equal to the soaking surcharge. To prevent upheaval of soil into the hole of the surcharge weights, it is advisable to place one 5-lb annular disk surcharge weight on the soil surface prior to seating the piston and finally applying the remainder of the weights.

3.1.2 *Seating piston.* To seat the penetration piston, bring it into contact with the sample with sufficient pressure to cause the load dial to register a load of between zero and 1 lb.

3.1.3 *Applying loads.* Apply loads on the penetration piston so that the rate of penetration is approximately 0.05 in. per minute. Obtain load readings at 0.025-. 0.050-, 0.075-, 0.100-, 0.125-, 0.150-, 0.175-, 0.200-, and 0.300-in. deformation. In manually operated loading devices, it may he necessary to take load readings at closer intervals to control the rate of penetration.

3.1.4 *Determining moisture content* Determine the moisture content in the upper 1 in., and in the case of

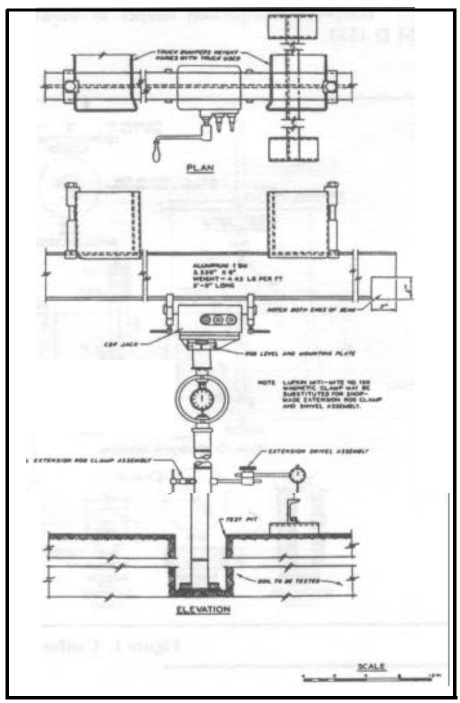


Figure 3. CBR testing equipment

CALIFORNIA BEARING RATIO (CBR) TEST
Penetration

PROJECT			DATE
SAMPLE NO.			JOB NO.
NO. BLOWS		AS MOLDED	SOAKED
MOLD NO.	Surcharge weights, in pounds: Soaking ______ Penetration ______		

Date	Time	Days	Reading in.	Swell in.	Swell %	BEARING RATIO DATA (3-sq-in. piston, 0.05 in. per min.)			
						Penetration in.	Total Load	Bearing Value* lb/in.^{2}	Corr. CBR
		0	0.	0.					
			0.	0.					
			0.	0.		0.025			
			0.	0.		0.050			
			0.	0.		0.075			
			0.	0.		0.100**			
			0.	0.		0.125			

WATER CONTENTS AFTER SOAKING	Whole Specimen Drained	Top in.	Penetration in.	Total Load	Bearing Value* lb/in.^{2}	Corr. CBR
			0.150			
			0.175			
Tare			0.200†			
Tare + wet soil			0.250			
Tare + dry soil			0.300			
Water			0.350			
Tare			0.400			
Solids			0.450			
Water Content	%	%	0.500			

Note: Standard load at 0.1-in. penetration = 1000 psi.
Standard load at 0.2-in. penetration = 1500 psi.
* (0.734 x total load in kilograms) or (total load in pounds ÷ 3).
** Total load in pounds ÷ 30 = CBR.
† Total load in pounds ÷ 45 = CBR.

TECHNICIAN	CHECKED	DATE

Figure 4. CBR laboratory record form

laboratory tests determine an average moisture content for the entire depth of the sample.

3.2 *Procedure for soaking laboratory CBR specimens.*

3.2.1 *Placement of masses.* Place the adjustable stem and plate on the surface of the sample, and apply an annular mass to produce an intensity of loading equal to within ±5 lb of the mass of the base material and pavement that overlie the soil being tested, but in no case should the surcharge mass be less than 10 lb.

3.2.2 *Placement of tripod.* Set tripod on mold and dial stem on adjustable stem from plate and make initial measurement from which to determine swell or consolidation of specimen.

3.2.3 *Soaking specimen.* Immerse the mold in water to allow free access of water to top and bottom, and allow the specimen to soak for 4 days. (A shorter soaking period is permissible for soils that take up moisture readily if tests show that a shorter period does not affect the results.)

3.2.4 *Final measurements.* Make final swell or consolidation measurements and calculate the swell or consolidation as a percentage of the initial specimen height.

3.2.5 *Draining specimen.* Wipe the free water from the specimen, being careful not to disturb the surface of the specimen; then allow it to drain for 15 minutes. It may be necessary to tilt the specimen in order to achieve good drainage.

3.2.6 *Weighing specimen.* Remove the perforated plate and surcharge weights and weigh the specimen. The specimen is now ready for the penetration test.

3.3 *General procedure for testing laboratory-compacted CBR specimens.*

3.3.1 *Soil grouping* for *test purposes.* For testing laboratory-compacted specimens for the CBR method of design, materials have been grouped into three classes with respect to behavior during saturation: (a) cohesionless sands and gravels, (b) cohesive soils, and (c) highly swelling soils. The first group usually includes the GW, GP, SW, and SP classifications of ASTM D 2487. The second group usually includes the GM, GC, SM, SC, ML, CL, and OL classifications. Swelling soils usually comprise the MH, CH, and OH classification. Separate procedures are given for each of the groups.

3.3.2 *Cohesionless sands and gravels.* Cohension-less soils usually compact readily under rollers or traffic. Specimens shall be prepared, as specified in CRD-C 653 at high densities and at a range of moisture contents bracketing those anticipated in the field, including moisture contents as high as practicable. If soaking does not lower the CBR, it may be omitted for further tests on the same material.

3.3.3 *Cohesive soils.*

3.3.3.1 *Specimen preparation and compaction curves development.* Representative samples of cohesive soils are tested in a manner to develop data that will show their behavior over the entire range of anticipated moisture contents. Test specimens are prepared and compaction curves are developed for the CE 55, CE 26, and CE 12 compaction efforts as described in CRD-C 653. Each specimen shall be soaked and penetrated to develop a complete family of curves showing the relation between density, moisture content, and CBR. To aid in determining the validity of the compaction data, a semilog plot of maximum density versus compaction effort in energy per unit volume usually gives a straight-line relation as illustrated in CRD-C 653.

FIELD CBR TEST 1. Date ________ 19 ____

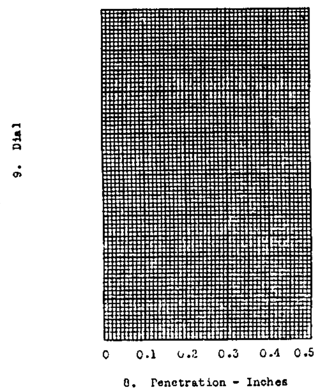
2. Project ____________ 3. Project Location ____________

4. Test Location ____________

____________ 5. Material ____________

6. Depth, In. ______ 7. Failed / Unfailed 10. Proving Ring No. ____________

8. Pene.	9. Dial	8. Pene.	9. Dial	8. Pene.	9. Dial
.025"		.175"		.325"	
.050"		.200"		.350"	
.075"		.225"		.375"	
.100"		.250"		.400"	
.125"		.275"		.450"	
.150"		.300"		.500"	



CBR at 0.1"

11. Corrected Dial ______

12. CBR ______ %

CBR at 0.2"

13. Corrected Dial ______

14. CBR = ______ / 1.5 = ______ %

	15. Water Content for CBR	16. Water Content for Dens.	17. Density Sample
18. Container No.			
19. Wet Soil + Container			
20. Dry Soil + Container			
21. Wt Water			
22. Wt Container			
23. Wt Wet Soil			
24. Wt Dry Soil			
25. Water Content			
26. "K" Factor			
27. Unit Wet Wt			
28. Unit Dry Wt			

29. Sand Volume	
30. Wt Filled	
31. Wt Empty	
32. Wt Sand	
33. Vol. Container	
34. Calibrated Dens.	
35. Wt After	
36. Wt Sand	
37. Wt After	
38. Wt Sand	
39. Wt Sand Used	

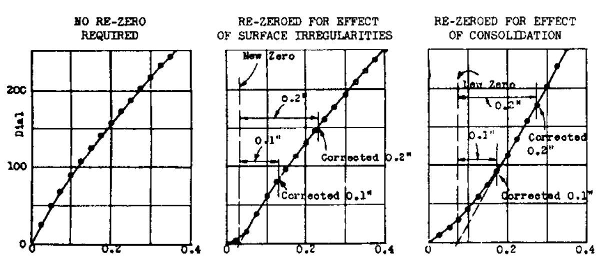
40. Remarks ____________

41. Field Test By ______ 42. Lab. Test By ______ 43. Comptd. By ______ 44. Chkd ______

Figure 5. CBR field record form

1. Date. Date field test is made.
2. Project. Write name of job.
3. Project Location. Give location of job.
4. Test Location. Describe location of test pit on job.
5. Material. Material being tested; base, subgrade, etc.
6. Depth. Depth from surface in inches.
7. Failed or Unfailed. Circle apt term.
8. Penetration. Penetration of CBR piston into soil in inches.
9. Dial. Reading on proving ring dial. When plotting the curve select the largest reasonable scale that will include the maximum value obtained in the test. Be sure to show this scale on the plot.
10. Ring No. Serial Number of proving ring (for selecting calibration sheet).
11. Corrected Dial. Plot curve of dial readings versus penetration and re-zero curve as shown in samples below. Read dial at corrected 0.1 in.
12. CBR. Read CBR from calibration curve (calibration curve reads direct CBR).
13. Corrected Dial. Same as 11 except read dial at corrected 0.2 in. penetration.
14. CBR. Same as 12 except divide reading from calibration sheet by 1.5. Show to nearest per cent.
15. Use this column for the water content from the CBR test.
16. Use this column for the water content from the density sample.
17. Use this column for the soil part of sand volume/sample or for the entire computations in cylinder samples.
18. Self explanatory.
19. and 20. Show weight in grams.
21, 22, 23, 24. For columns 15 and 16 obtain 24 first by subtracting 22 from 20. Then obtain 21 by subtracting 20 from 19. For column 17 obtain 23 by subtracting 22 from 19 when computing cylinder densities.
25. Water content is 21 divided by 24 multiplied by 100 per cent. Show nearest 0.1%.
26. "K" Factor for cylinder obtained by following formula; K equals 4.85 over diameter squared times height.
27. For sand apparatus densities; 23 times 34 over 39. For cylinder densities; 23 by 26.
28. 27 divided by 1 plus water content in hundredths. Example: 1 plus water content of 16.7 equals 1.167. May also be computed in the same manner as 27 by using the dry weight of soil 24 in place of the wet weight 23. Show to the nearest lb/cu ft.
29. Use for sand part of sand volume density.
30. Total weight of sand apparatus filled in grams.
31. Total weight of sand apparatus empty in grams.
32. Weight of sand used to fill cylinder; obtained by subtracting line 31 from line 30.
33. Volume of sand apparatus used. Obtained by using formula: weight of water required to fill cylinder in pounds over unit weight of water in lb/cu ft.
34. Density of sand in lb/cu ft obtained by multiplying line 32 by .002205 over line 33.
35. Re-weigh for total weight of sand apparatus in grams after pouring sand for surface calibration.
36. Total weight of sand used in surface calibration obtained by subtracting line 35 from line 30.
37. Re-weigh after filling hole for amount of sand used in hole.
38. Total weight of sand used in hole and surface calibration obtained by subtracting line 37 from line 35.
39. Weight of sand used in hole obtained by subtracting line 36 from line 38.
40. Explain any variations. Also use to record additional facts about test location.
41, 42, 43, 44. Insert initials.

Use figures in block for making tables and plots, except use underlined CBR (0.2 in.) when this figure is constantly higher for material being tested.



These curves show a case requiring no re-zeroing and two typical cases where re-zeroing is required. The curves themselves are not necessarily typical as the slope and shape of curves vary considerably. In general, the points should line up so that reasonable curves can be drawn with a French curve. Tests should be re-run where the points do not line up sufficiently well to permit drawing reasonable curves.

Figure 6. CBR field record form (reverse side)

3.3.3.2 *Obtaining design CBR data*. The data from a CBR test are plotted as in Figure 7, and the resulting family of CBR curves represents the characteristics encompassing a wide range of field conditions. The design CBR shall be based on the density and molding moisture content anticipated in the field. For example, assume that the lean clay soil, for which results are plotted in Figure 7, can be processed to an average moisture content of 13 percent to 16 percent and that it can be compacted to a density varying from 110.5 (95 percent of modified maximum density) to 115 Ib/ft^3 (see cross-hatched area on lower left-hand plot of Figure 7). If construction could be controlled so that the density and moisture content were within these ranges, the right-hand plot of Figure 7 indicates that the soils, after moisture conditions had become adjusted, would have a CBR (see cross-hatched area on right-hand lot of Figure 7) varying between about 11 (1105-lb/ft^3 density and 13 percent moisture content) and 26 (1l54lb/ft^3 density and 15 percent moisture content). The design CBR selected should be near the lower value, say 12. The right-hand plot in Figure 7 shows that close control of moisture content within those limits (13 percent to 16 percent) is necessary because low CBR values will be obtained if the moisture content is allowed to increase appreciably above the desired range.

3.3.4 *Swelling soils*.

3.3.4.1 *Test procedures. The* test procedures for highly swelling soils are the same as those previously described for cohesive soils; however, the objectives of the testing program are not exactly the same. Tests shall be performed on soils having expansive characteristics to determine a moisture content and a density which will minimize expansion. The proper moisture content and density are not necessarily the optimum moisture content and density for the CE 55 compaction effort. Generally, the minimum swell and highest soaked CBR will occur at a molding moisture content slightly wet of optimum. When testing highly swelling

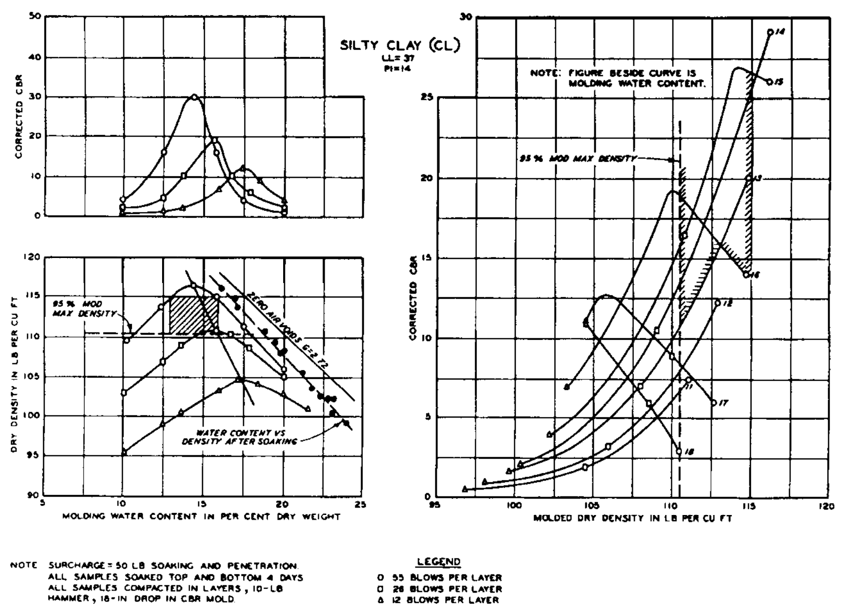


Figure 7. Recommended procedure for performing CBR tests for design

soils, it may be necessary to prepare samples for a wider range of moistures and densities than normally used to establish the relation between moisture content, density, swell. and CBR for a given soil. A careful study of the test results will permit the selection of the proper moisture content and density required in the field. It should be noted that the possibility exists that thickness design may be governed by the compaction requirements instead of the CBR in some cases.

3.4 *Field in-place tests (see* Figures 5 and 6 for data sheet). Field in-place CBR tests are used for design under any one of the following conditions: (a) when the in-place density and water content are such that the degree of saturation (percentage of voids filled with water) is 80 percent or greater; (b) when the material is coarse grained and cohesionless so that it is not affected by changes in water content; and (c) when construction was completed several years before. In the last-named case, the water content does not actually become constant but appears to fluctuate within rather narrow ranges, and the field in-place test is considered a satisfactory indicator of the load-carrying capacity. The time required for the water content to become stabilized cannot be stated definitely, but the minimum time is approximately 3 years.

3.4.1 *Penetration.* Level the surface to be tested, and remove all loose material. Then follow the procedure described in 3.1.1.

3.4.2 *Number of tests.* Three in-place CBR tests should be performed at each elevation tested in the base course and at the surface of the subgrade. However, if the results of the three tests in any group do not show reasonable agreement, three additional tests should be made at the same location. A reasonable agreement between three tests where the CBR is less than 10 permits a tolerance of 3; where the CBR is less than 10 permits a tolerance of 3; where the CBR is from 10 to 30, a tolerance of 5; and from 30 to 60, a tolerance of 10. For CBR's above 60, variations in the individual readings are not of particular importance. For example, actual test results of 6, 8, and 9 are reasonable and can be averaged as 8; results of 23, 18, and 20 are reasonable and can be averaged as 20. If the first three tests do not fall within the specified tolerance, the three additional tests are made at the same location, and the numerical average of the six tests is used as the CBR at that location.

3.4.3 *Moisture content and density.* After completion of the CBR test, a sample shall be obtained (a) at the point of penetration for moisture-content determination, and (b) 4 to 6 in. away from the point of penetration for density determination.

3.5 *Undisturbed specimens.* Because of the difficulty of obtaining reliable CBR test results on so-called undisturbed specimens, these tests will be performed only in special cases.

Note: The past practices of obtaining and testing samples in wooden boxes and of leaving an annular space between sample and container wall to be filled with plastic material such as paraffin shall be discontinued because these practices leave some doubt as to the adequacy of the lateral confinement of specimen during the CBR test.

4. Calculations.

4.1 *Calculation procedures.* The CBR shall be calculated immediately after completion of the test, as follows.

4.1.1 *Plotting load-penetration curve.* Calculate the penetration load in lb/in.* and draw the load-penetration curve. It is sometimes necessary to correct the CBR value because of surface irregularities and/or the concave-upward shape of the curve that characterizes samples on the wet side of optimum for certain soils. Figure 8 shows both the uncorrected and the corrected CBR curves. Correction can be made graphically by adjusting the zero point of the curve as

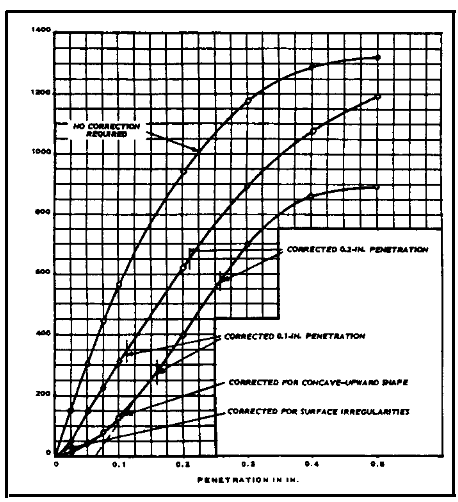


Figure 8. Correlation of stress-penetration curve

in Figure 8, or it can be made mathematically by selecting the largest CBR value based on load increase divided by the standard loads for any consecutive 0.1- or 0.2-in. penetration. The mathematical correction has the advantage of eliminating the personal error in drawing the corrected curve. However, the curve should be drawn in any case so that erratic data will be more easily recognized.

4.1.2 *Calculating CBR.* Determine the corrected load values at 0.1- and 0.2-in. penetration from which the CBR values are obtained by dividing the corrected unit loads at 0.1 and 0.2 in. by the standard loads of 1,000 and 1,500 psi, respectively. Each ratio is multiplied by 100 to obtain the bearing ratio in percent. The CBR is usually selected at 0.1-in. penetration. If the ratio at 0.2-in. penetration is greater, the test should be rerun. If check tests give similar results, use the CBR at 0.2-in. penetration.

4.1.3 *Design CBR* value. The specific design CBR values from field test may be determined following procedures indicated in the appropriate flexible pavement design manuals.